Cloud Top Pressure Retrievals

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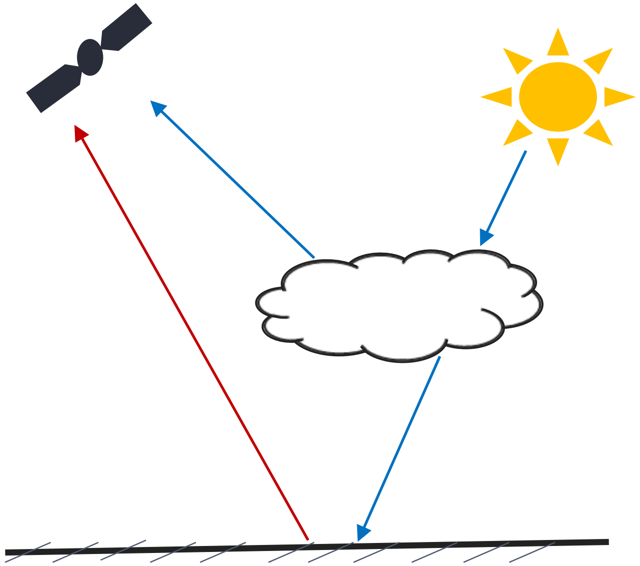
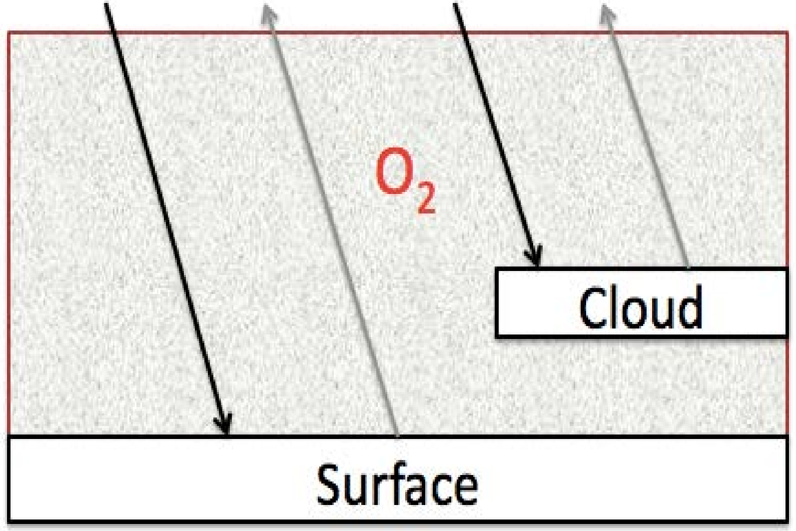
Cloud Top Information:

Mixed Lambertian Equivalent Reflectivity (MLER)



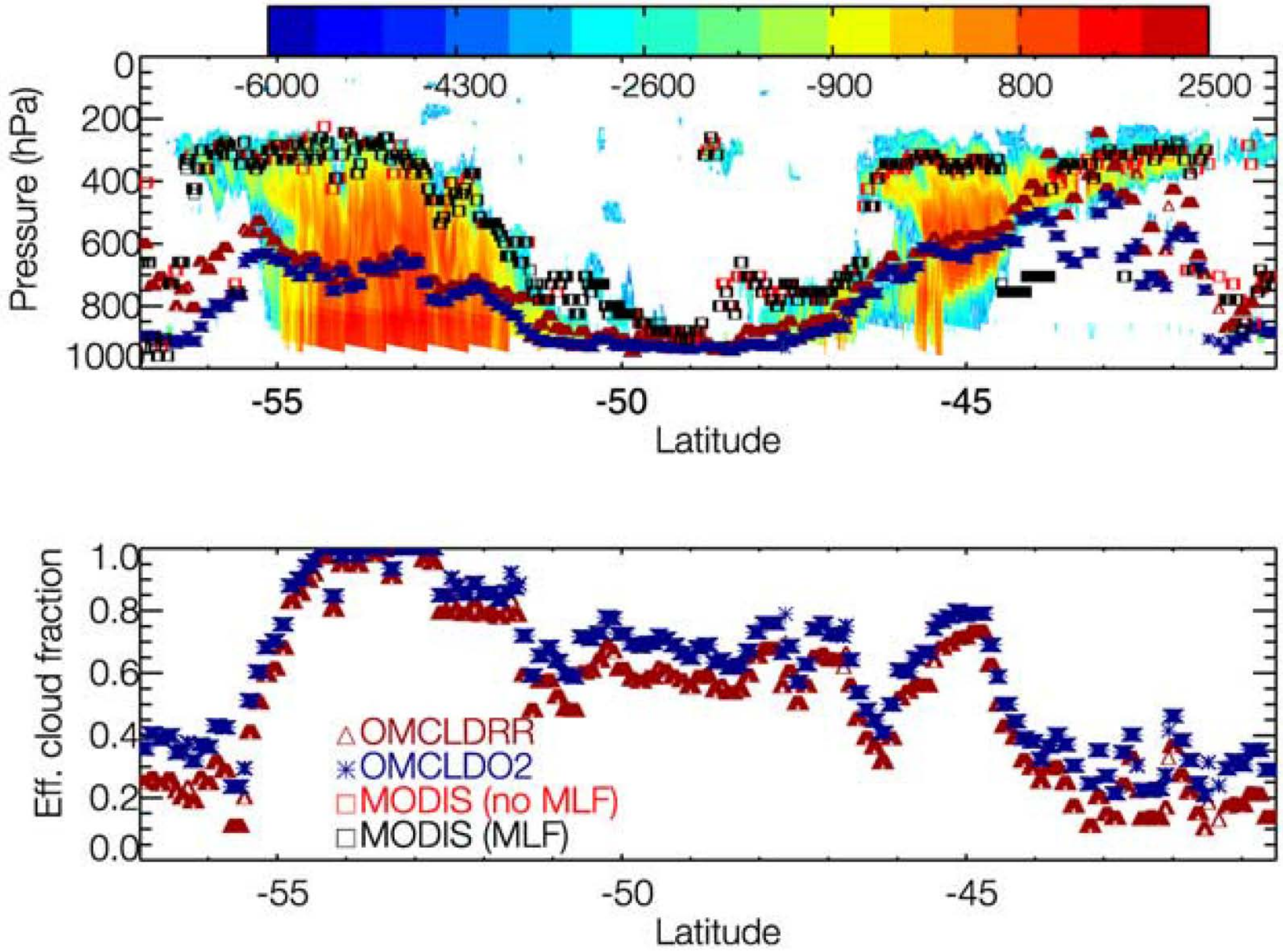


$$R_{abs}(\theta,\theta_0) = (1-A_c)\alpha_s T_{abs}(P_s,\theta,\theta_0) + A_c \alpha_c T_{abs}(P_c,\theta,\theta_0) \quad (1)$$

$$R_{ref}(\theta,\theta_0) = (1-A_c)\alpha_s T_{ref}(P_s,\theta,\theta_0) + A_c \alpha_c T_{ref}(P_c,\theta,\theta_0) \quad (2)$$

Cloud Top Information:

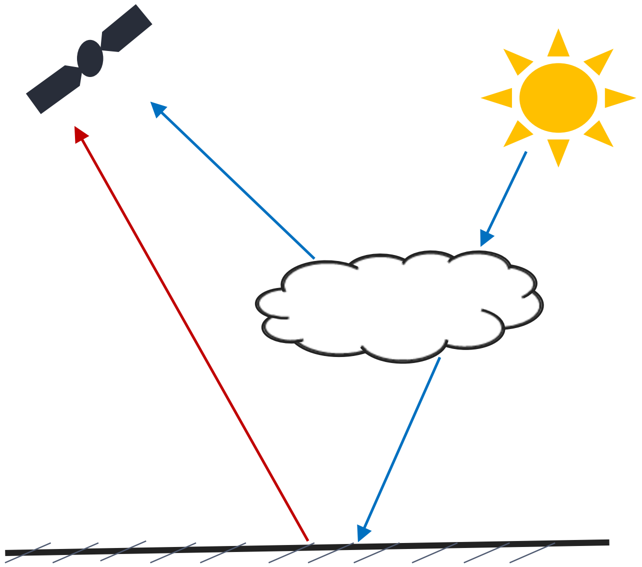
Mixed Lambertian Equivalent Reflectivity (MLER)



Vasilkov et al (2008)

Cloud Top Information:

Photon path length and penetration



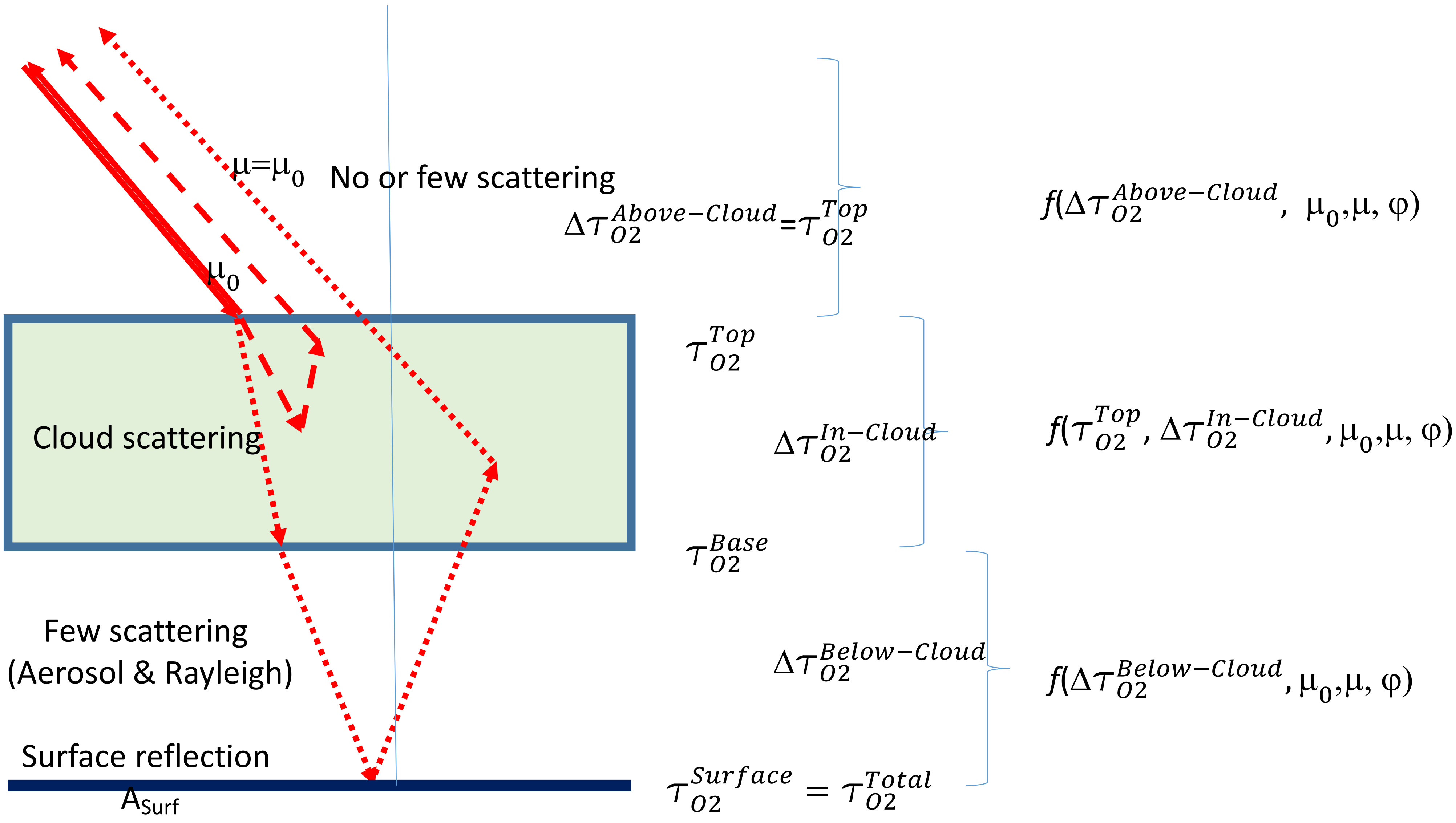
- ❑ Clouds:
  - ❖ Cloud Top Pressure
  - ❖ Cloud Optical Property
  - ❖ Cloud Thickness
  - ❖ Cloud Faction
- ❑ Atmospheric Profiles

✓ Maximizing information content

✓ Minimizing inconsistent assumptions for all cloud retrievals

Equivalence theorem: to separate absorption from scattering

Absorption: Weak/strong absorption approximation
Scattering: Single scattering or asymptotic approximation



Above Cloud:

- ❑ Equivalence theorem to separate absorption from scattering

$$f(\Delta\tau_{O2}^{Above-Cloud},\ \mu_0,\mu,\varphi) = f(\Delta\tau_{O2}^{Above-Cloud})f(\mu_0,\mu,\varphi) = \tau_{O2}^{Top}(\frac{1}{\mu}+\frac{1}{\mu_0}) = \frac{2}{\mu_0}\tau_{O2}^{Top}$$

Within Cloud:

- ❑ Due to photon penetration, two oxygen parameters influence the enhanced path length absorption:

$$\frac{\partial(\tau_{O2}^{Top})}{\partial\tau} \sim \tau_{O2}^{Top}\ ;\ \Delta\tau_{O2}^{In-Cloud} = \tau_{O2}^{Base} - \tau_{O2}^{Top}$$

- ❑ Equivalence theorem to separate absorption from scattering

$$f(\tau_{O2}^{Top},\Delta\tau_{O2}^{In-Cloud},\mu_0,\mu,\varphi) = f(\tau_{O2}^{Top},\Delta\tau_{O2}^{In-Cloud})f(\mu_0,\mu,\varphi)$$
$$= f(\tau_{O2}^{Top})f_1(\mu_0,\mu,\varphi) + f(\Delta\tau_{O2}^{In-Cloud})f_2(\mu_0,\mu,\varphi)$$

Within Cloud:

- Strong (~ $\sqrt{\tau_{O2}^{Top}}$) and weak (~ τ_{O2}^{Top}) absorption dependences

$$f(\tau_{O2}^{Top}) = a1\sqrt{\tau_{O2}^{Top}} + b1\,(\tau_{O2}^{Top})$$

- Based on asymptotic approximation,

$$R(\tau,\mu_0,\mu,\varphi) = R_\infty(\tau,\mu_0,\mu,\varphi) - TK(\mu)K(\mu_0)$$
$$= R_\infty(\tau, f_1(\mu,\mu_0)) - Tf_2(\mu,\mu_0)$$

Where T is transmittance and $f1$ and $f2$ functions have quadratic form

$$f(\tau_{O2}^{Top}, \Delta\tau_{O2}^{Cloud}, \mu_0,\mu,\varphi) = (a1\sqrt{\tau_{O2}^{Top}} + b1\,(\tau_{O2}^{Top}))(a2*T+b2*(\mu+\mu_0)+c2*T*(\mu+\mu_0)+d2\mu\ \ \mu_0)$$
$$+\ \Delta\tau_{O2}^{In-Cloud}(a3*T+b3\,(\mu+\mu_0)+c3*T*(\mu+\mu_0)+d3\mu\ \ \mu_0)$$

Below Cloud:

- Similar reasoning as to within cloud

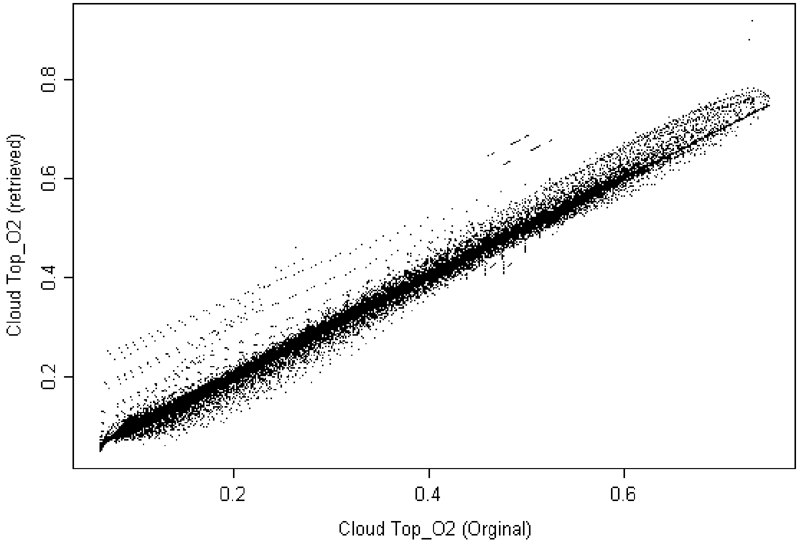
$$f(\Delta\tau_{O2}^{Below-Cloud}, \mu_0,\mu,\varphi) = T\tau_{O2}^{Below-Cloud}\frac{A_{Surf}}{1+(e4*T+f4)*A_{Surf}}\ (a4*T+b4\,(\mu+\mu_0)+c4*T*(\mu+\mu_0)+d4\mu\ \ \mu_0)$$

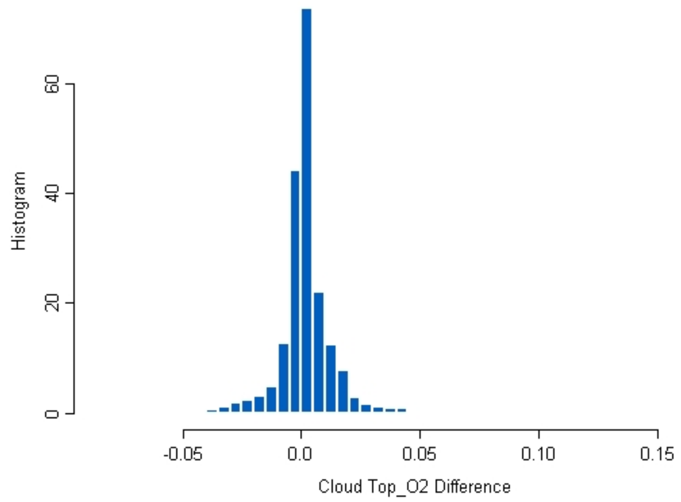
The analytical EPIC model:

$$-\log\left(\frac{R_A}{R_f}\right) = \frac{2}{\mu_0}\tau_{O2}^{Top}$$
$$+\left(a1\sqrt{\tau_{O2}^{Top}} + b1(\tau_{O2}^{Top})\right)(a2*T+b2*(\mu+\mu_0)+c2*T*(\mu+\mu_0)+d2\mu\ \ \mu_0)$$
$$+\ \Delta\tau_{O2}^{In-Cloud}T(a3*T+b3\ (\mu+\mu_0)+c3*T*(\mu+\mu_0)+d3\mu\ \ \mu_0)$$
$$+\ \Delta\tau_{O2}^{Below-Cloud}\frac{A_{Surf}}{1+(e4*T+f4)*A_{Surf}}T(a4*T+b4\ (\mu+\mu_0)+c4*T*(\mu+\mu_0)+d4\mu\ \ \mu_0)$$

The coefficients are determined through nonlinear regression.

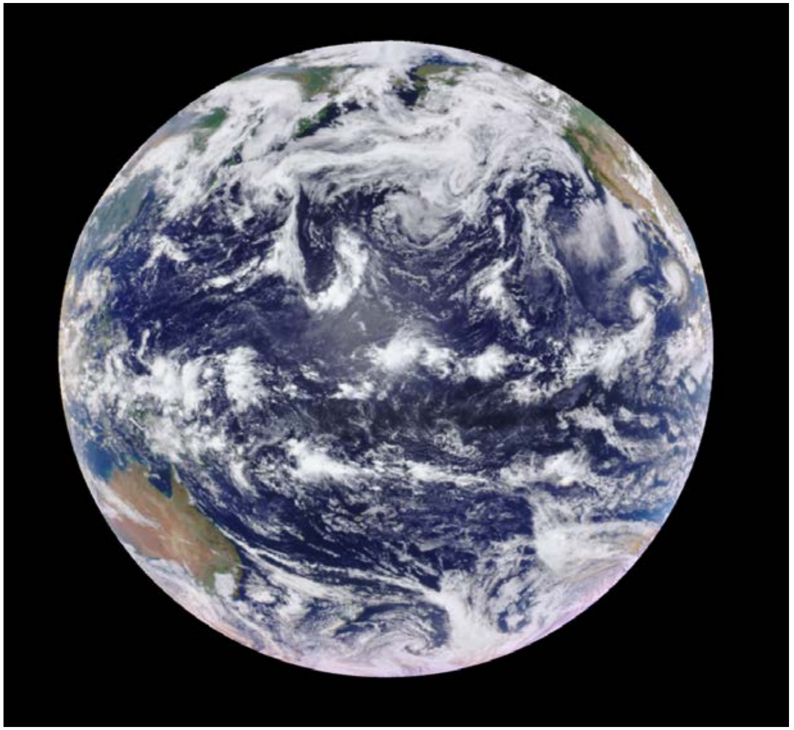
Solving the quadratic equation, $A(\sqrt{\tau_{O2}^{Top}})^2 + B\sqrt{\tau_{O2}^{Top}} + C = 0$, to retrieve cloud top O2 depth, and then cloud top pressure

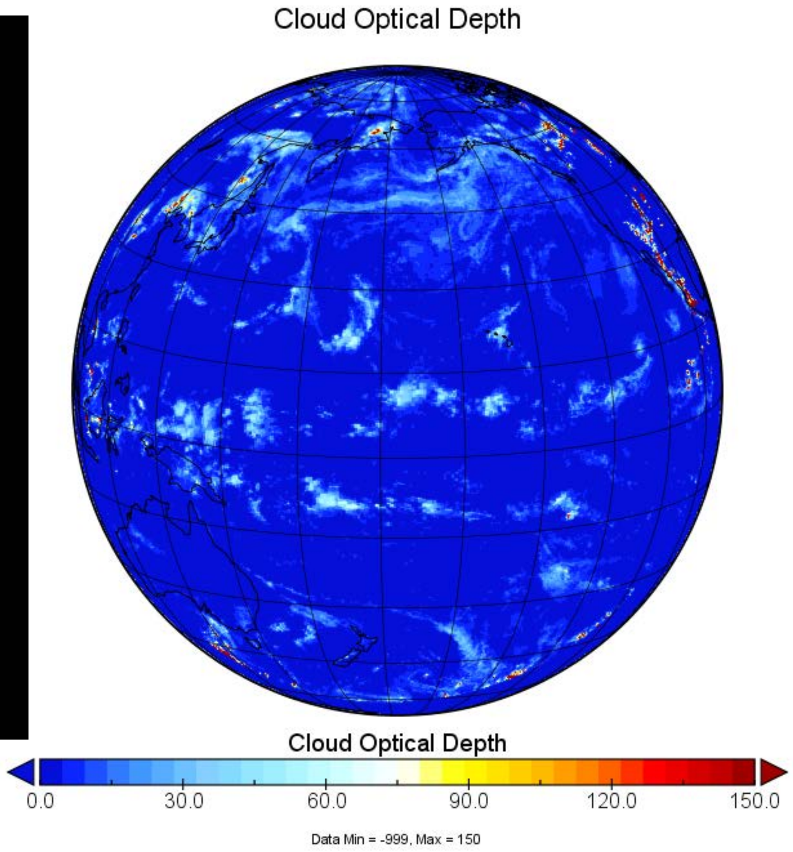


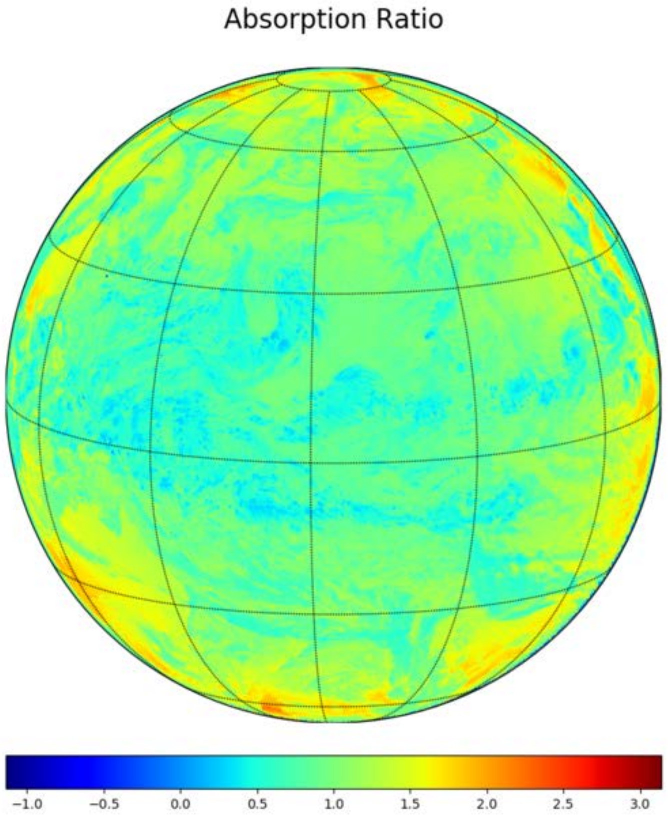


SDE = 0.015 (t_{O2}) or ~ 10 mb

Case: epic_1b_20160725001751_01.h5







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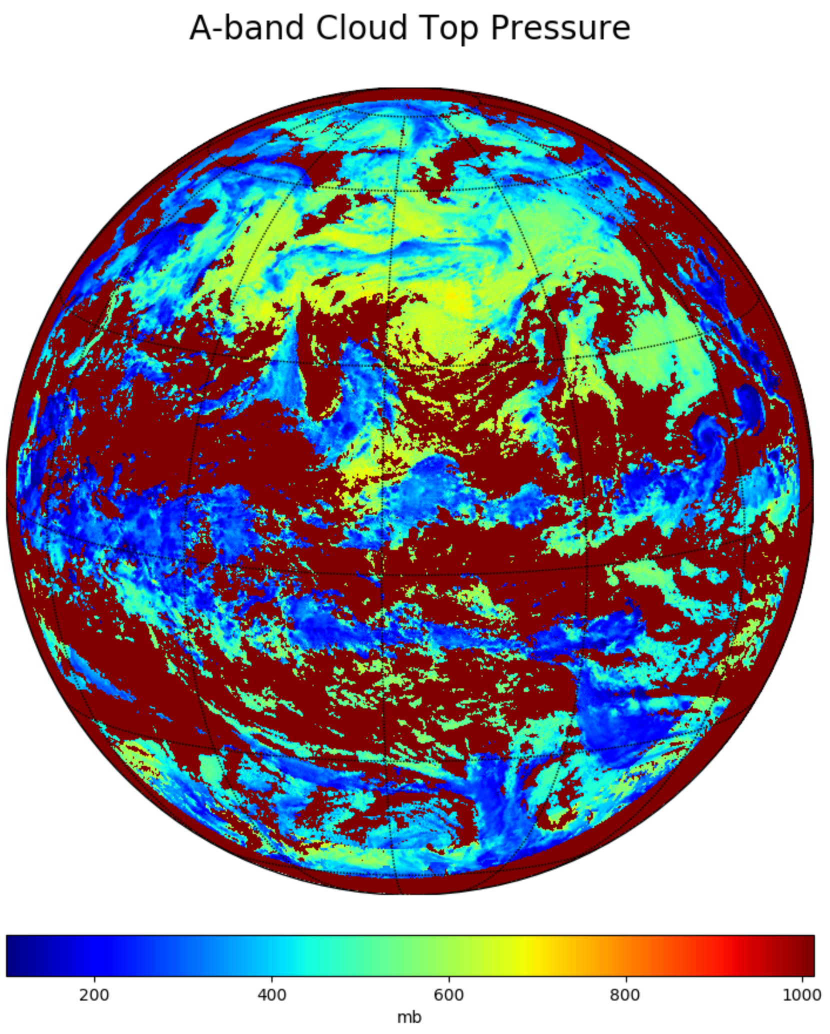

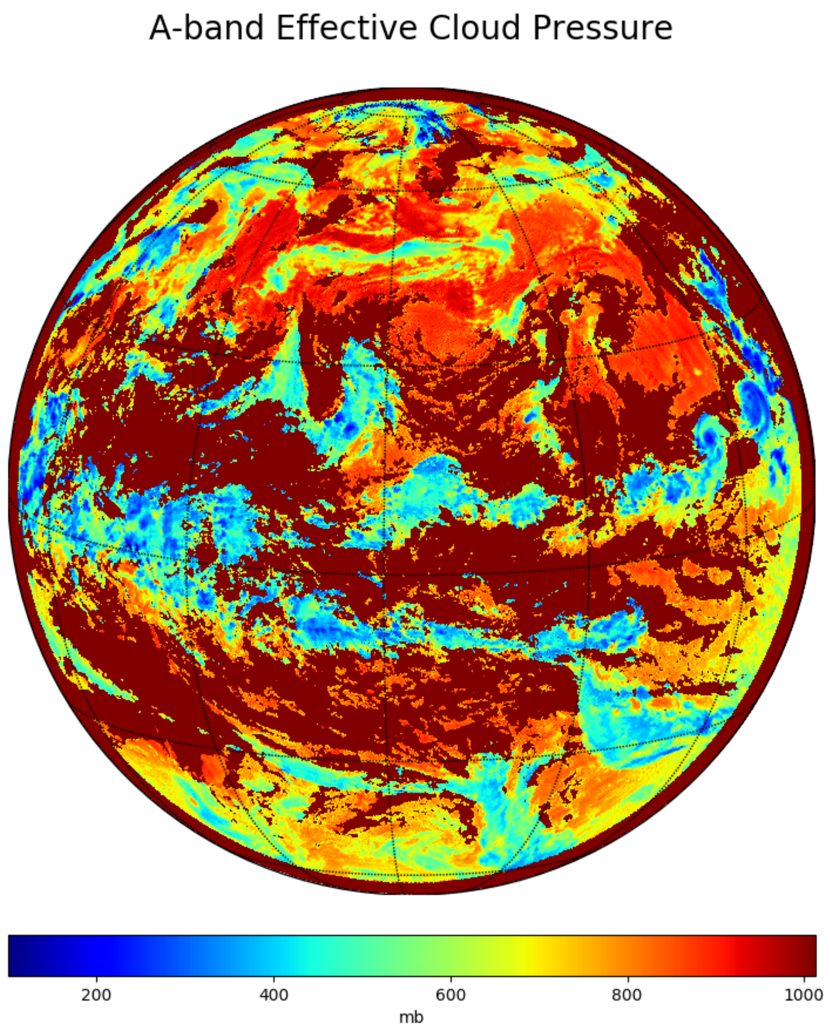

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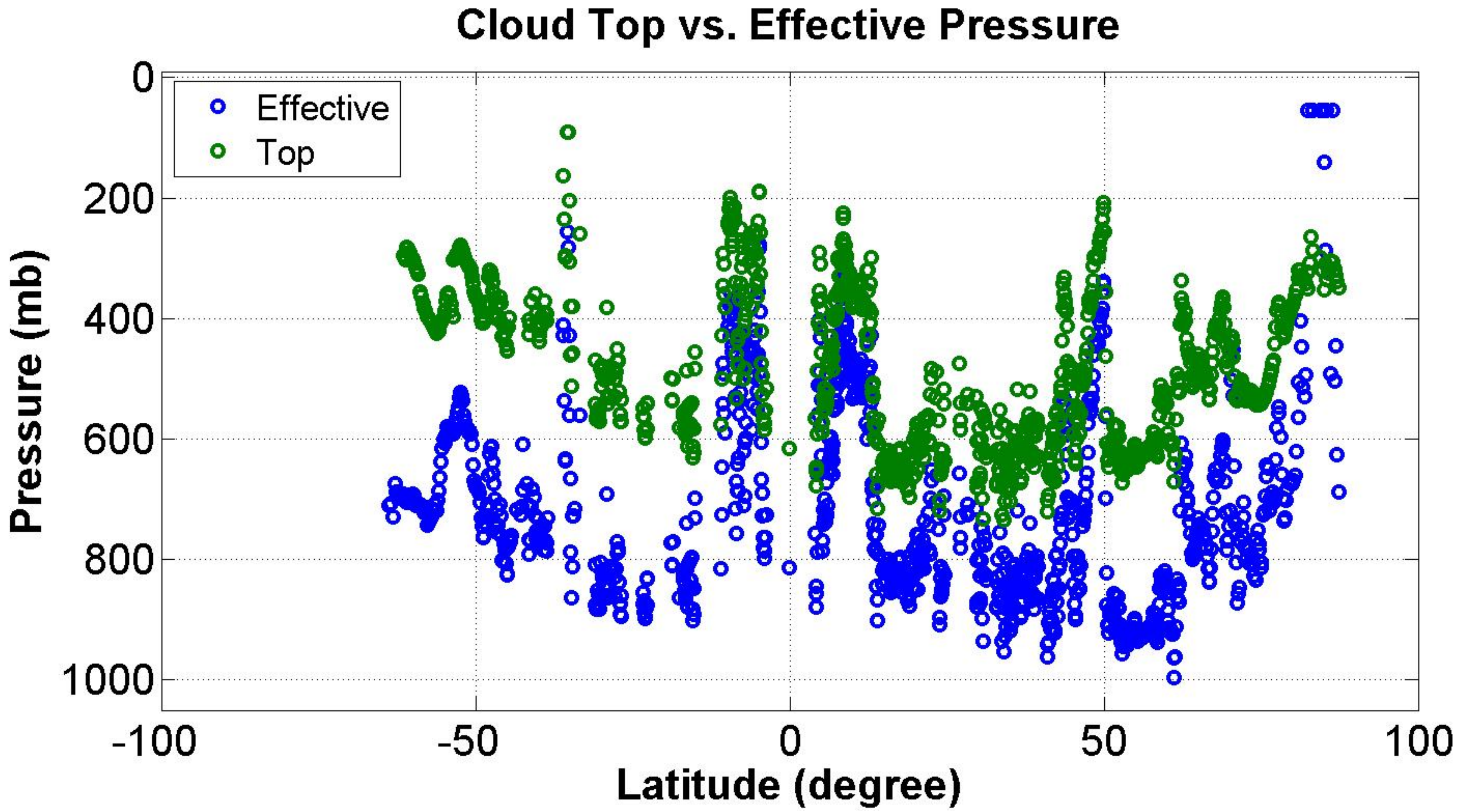

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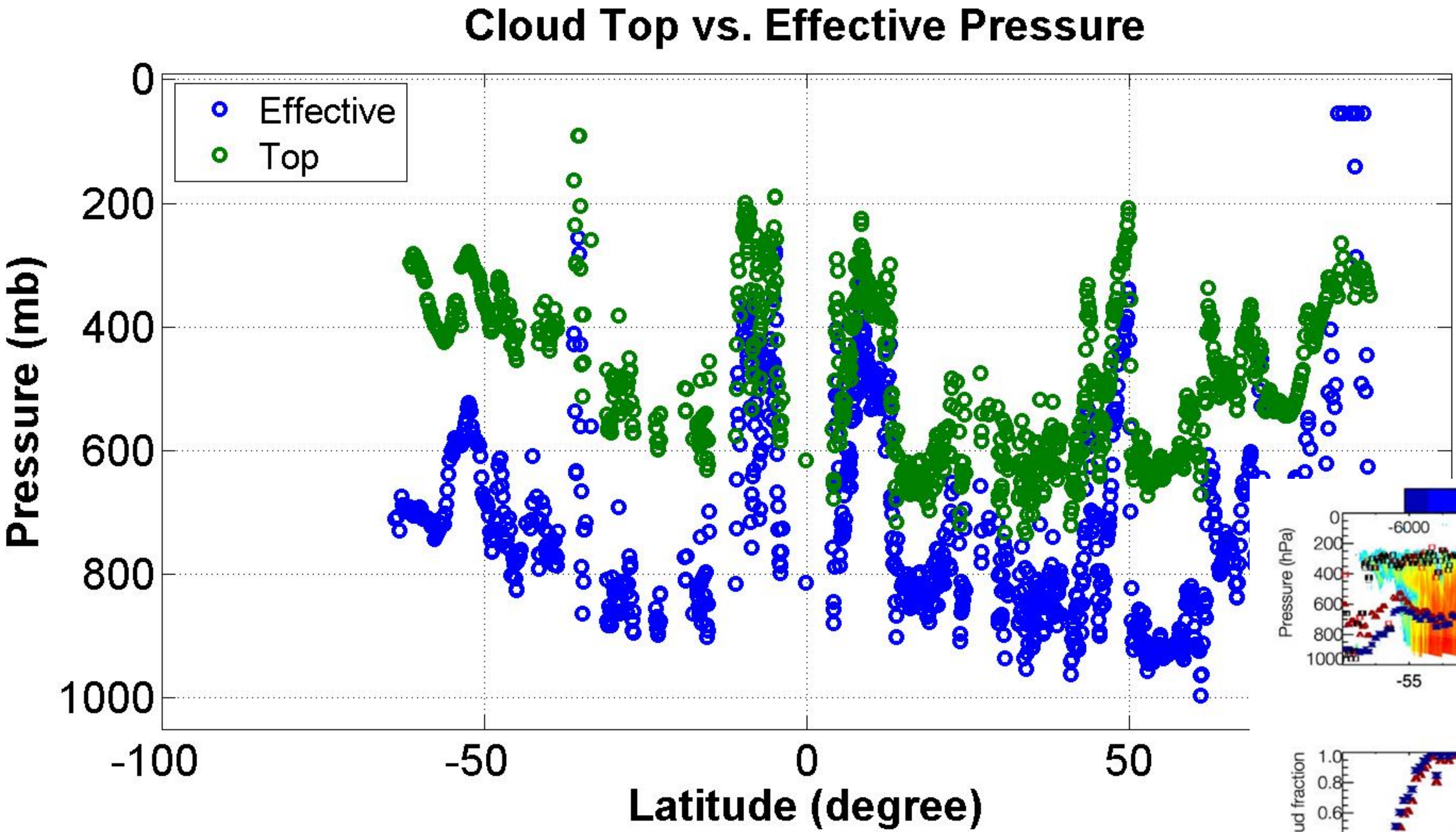
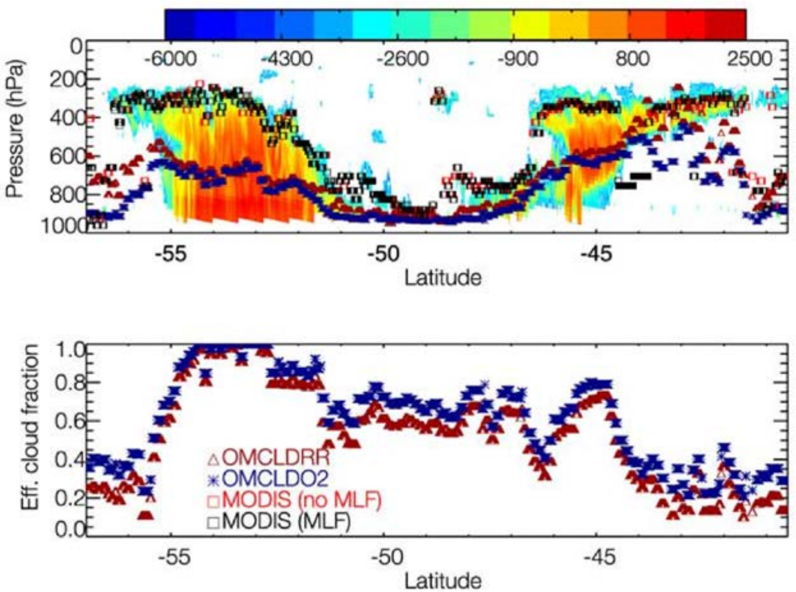




Ongoing and future works:

- Evaluation and validation

- Algorithm improvements

    - Self-consistent assumptions
    - Conversion from oxygen absorption to pressure (to altitude)
    - Partial cloud issues

Conversion from oxygen absorption to pressure (to altitude)

Develops the fitting coefficients and applies them to a given atmospheric profile

- The same coefficients can be used for **any atmosphere**
- High accuracy compared to full LBLRTM-calculated absorption

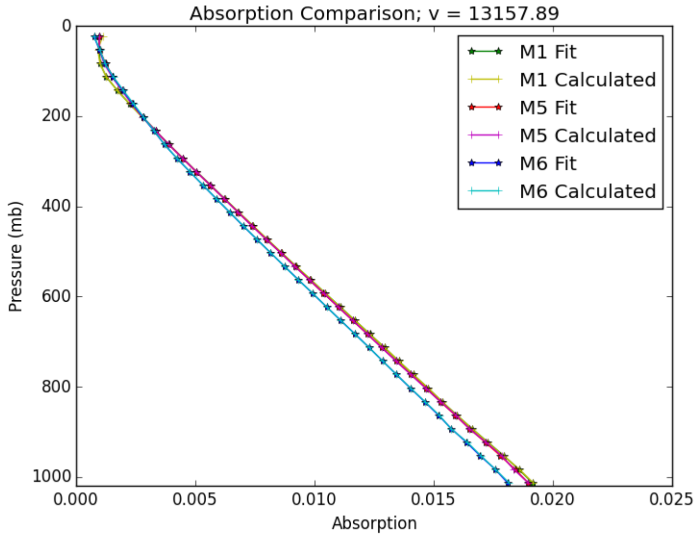
$$A_{vLM} = [a_0(v,P) + a_1(v,P) \times (T_{LM} - T_{mL}) + a_2(v,P) \times (T_{LM} - T_{mL})^2] \times \rho_{O_2}$$

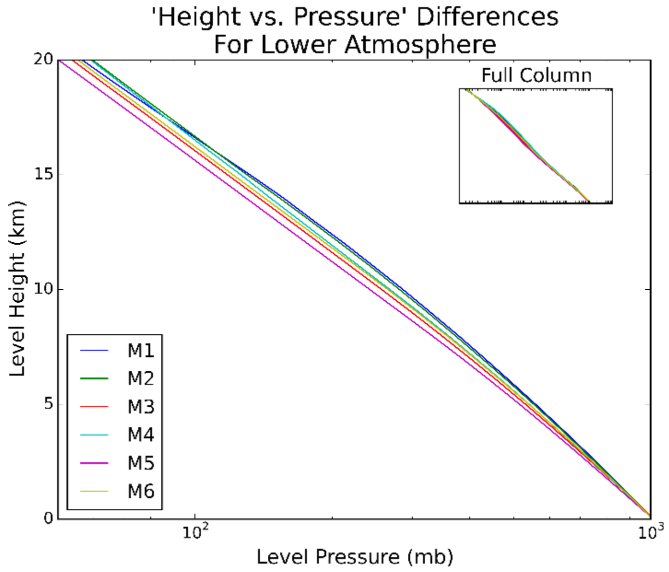
A_{vLM} : Optical depths for layer L, spectral point v, and atmosphere M

ρ_{O_2}: molecular column density ($\frac{molecules}{cm^2} \times 10^{-23}$)

T_{LM} = average temperature for layer L for a given atmosphere

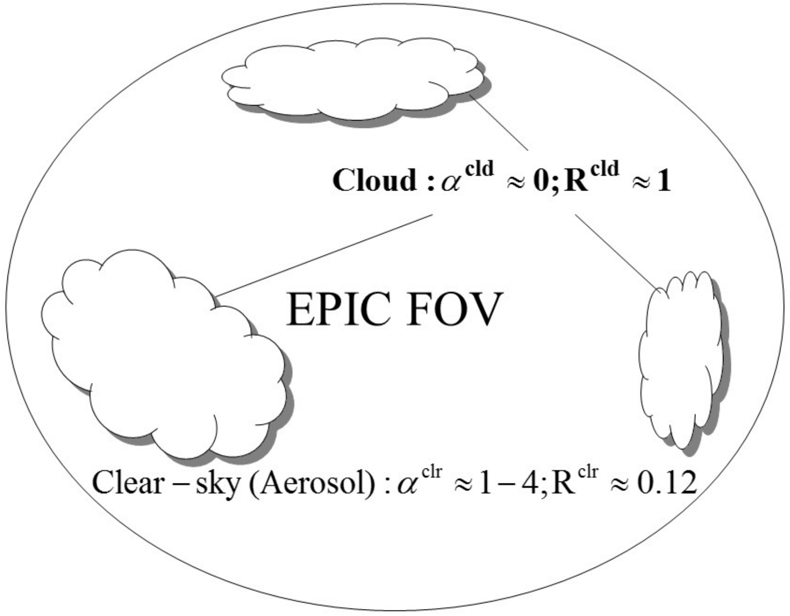
T_{mL} = average temperature over all atmospheres (M1→ M6) for layer L





Cloud Fraction Cover:

- Spectral reflectance at 388(443) nm and 680(740) nm have big difference at clear and cloudy sky and thus have different partition between cloud and aerosol.
- Ratio of reflectance at 388(443) /680(746) is insensitive to SZA and view angles



$$R^{obs} = (1-\emptyset)R^{\mathrm{clr}} + \emptyset R^{cld}$$

$$\emptyset = \frac{R^{\mathrm{obs}} - R^{\mathrm{clr}}}{R^{\mathrm{cld}} - R^{\mathrm{clr}}}$$

MODIS cloud fraction | EPIC 680/443 | EPIC 746/443